PATENT

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Tomo UENO

Group Art Unit: 1762

Serial No.: 09/646,988

Examiner: Bret P. Chen

Filed: November 16, 2000

For: A METHOD FOR FORMING A FILM

DECLARATION UNDER 37 CFR 1.132

Tomo UENO declares that:

(1) he has expertise in electrical and electronic systems engineering, with special expertise in processing technologies for semiconductor devices;

(2) he has bachelor, master, and doctor degrees in electrical engineering, all from Waseda University, more particularly,

1991 Doctor of Engineering, Completion of Doctoral Course of Graduate School of Science and Engineering;

1988 Master of Engineering, Completion of Master's Course of Graduate School of Science and Engineering; and

1986 Bachelor of Engineering, Graduation from School of Science and Engineering;

(3) his work experience includes

2001 to date, Associate Professor, Tokyo University of Agriculture and Technology;

2000-2001, Assistant supervisor reseacher, New Energy and Industrial Technology Development Organization (NEDO);

2000, Associate Professor, Tokyo University of Agriculture and Technology;

1994-1999, full-time Lecturer, Tokyo University of Agriculture and Technology;

1992-1994, Research Assistant, Tokyo University of Agriculture and Technology; and

1990-1992, Research Assistant, School of Science and Engineering, Wasada University;

(4) he is familiar with the prosecution history of the captioned application;

(5) the following experiment was carried out under his direction and supervision to demonstrate the patentability of the present invention over the cited prior art, particularly to demonstrate the advantage of the use of only Kr and/or Xe gas as the inert gas component.

Experiment

The experiment was carried out using the film-forming equipment shown in Fig. 1 in this application.

First of all, the interior of the vacuum vessel 1 was evacuated to a pressure of no more than 1 x 10^{-5} Torr with the pump 100. A silicon substrate was then placed on the holder 8 and heated to 500°C. Thereafter, an inert gas and an oxygen gas were introduced into the vacuum vessel 1 through the quartz tube 4 until the interior pressure of the vacuum vessel 1 reached to 1 Torr. In this case, the mixture ratio of the inert gas and the oxygen gas was set to 25:1, and the total flow rate was set to 100 sccm. Then, a microwave with a frequency of 2.45MHz and a power of 100 W was introduced into the quartz tube 4 through the microwave cavity 3 to generate a plasma composed of the mixture of the inert gas and the oxygen gas. The silicon substrate was then exposed to the plasma for 50 minutes to form a SiO_2 film on the silicon substrate. He, Ne, Ar, Kr, and Xe were employed as the inert gases.

The thicknesses and the interface trap densities of the SiO_2 films are listed with respect to each inert gas.

Thickness of the SiO_2 film

inert gas: none (only oxygen gas)	2.0 nm
inert gas: He	2.8 nm
inert gas: Ne	3.2 nm
inert gas: Ar	3.5 nm
inert gas: Kr	8.3 nm
inert gas: Xe	6.8 nm

The thickness was measured with an ellipsometer using a light beam with a wavelength of 632.8 nm.

Interface trap density (Dit value) at the boundary between the SiO_2 film and the Si substrate

inert gas: none (only oxygen gas)	5×10^{12} (/cm^2/eV)
inert gas: He	4.5×10^{12} (/cm^2/eV)
inert gas: Ne	4.7×10^{12} (/cm^2/eV)
inert gas: Ar	3.1×10^{12} (/cm^2/eV)
inert gas: Kr	2.6×10^{11} (/cm^2/eV)
inert gas: Xe	7.8×10^{11} (/cm^2/eV);

(6) as to the thickness of the SiO_2 film, the use of the Kr gas or the Xe gas can enhance dissociation of the oxygen molecules into the oxygen atoms, and thus, enhance oxidation for the silicon substrate. As a result, the thickness of the SiO_2 film formed by

using the Kr gas or the Xe gas clearly is much larger than a SiO_2 film formed by using He gas, Ne gas, or Ar gas; and

(7) with the dit value, the use of the Kr gas or the Xe gas can dissociate the oxygen molecules into the oxygen atoms without ionization of the oxygen molecules. Therefore, the boundary between the SiO_2 film and the silicon substrate is not almost damaged by the ionized oxygen elements. In contrast, using He gas, Ne gas and Ar gas ionizes the oxygen molecules considerably. Therefore, the boundary between the SiO_2 film and the silicon substrate is minimally damaged by the ionized oxygen elements. As a result, the Dit value when using the Kr gas or the Xe gas is much smaller by single digit dimension than the one at the use of He gas, Ne gas or Ar gas.

The undersigned further declares that all statements made herein of his own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United

States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: Mar. 6, 2003

Tomo Ueno

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